12 GeV Upgrade Project

DESIGN SOLUTIONS DOCUMENT

Upgrade Hall A

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Approvals

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ACRONYMS

AC	Alternating current
ADC	Analog-to-Digital Converters
ALARA	As low as reasonably achievable
CHL	Central Helium Liquefier
DI	Deionized
DOE	Department of Energy
DX	Direct Expansion
EH&S	Environment, Health and Safety
fpm	Feet per minute
FPC	Fundamental Power Coupler
ft	Feet
HEPA	High-efficiency particulate air
HOM	Higher-Order Mode
HRS	High Resolution Spectrometer
Hz	Hertz
I&C	Instrumentation and Controls
ID	Internal diameter
in	Inch(es)
JLab	Thomas Jefferson National Accelerator Facility
kV	kilovolt
kW	kilowatt
LCC	Life-cycle cost
Linac	Linear accelerator
LLRF	Low level radio frequency
MHz	Megahertz
NFPA	National Fire Protection Association
ODH	Oxygen Deficiency Hazard
PPS	Personnel Protection System
psf	Pounds per square foot
psi	Pounds per square inch
rf/RF	Radio frequency
SBC	Standard Building Code
SF	Square feet
SRD	System requirements document
SRF	Superconducting Radio Frequency
TBD	To be determined
TDC	Time-to-Digital Converter
UL	Underwriters Laboratories
UPS	Uninterruptible power supply
WBS	Work Breakdown Structure

DESIGN SOLUTIONS DOCUMENT

Upgrade Hall A

1. System Description

The 12 GeV Upgrade Project scope is divided into three major systems: 1) Accelerator System, 2) Physics System, and 3) Civil Construction System. The Physics System is further divided into four systems: 1) Hall A Upgrade, 2) Hall B Upgrade, 3) Hall C Upgrade, and 4) Hall D.

The Physics System equipment planned for the Upgrade project takes full advantage of apparatus developed for the present program. In Hall A, the Upgrade will only add 11 GeV capability to the beamline. This hall will be used for special setup experiments, such as a Parity-Violating Møller scattering experiment, and have continued use for experiments where energy resolution sufficient to separate nuclear levels is important. This remains possible with the high resolution spectrometer pair in the hall, and the capability of the upgraded accelerator to deliver beams at 2.2, 4.4, and 6.6 GeV, which is compatible with the 4 GeV/c maximum momentum of these spectrometers.

2. Upgrade Hall A System Requirements

The Hall A System shall meet the following requirements:

- Provide electron beam polarimetry using the Compton Polarimeter at beam energies up to 11 GeV at presently achieved levels of accuracy (3%),
- Provide electron beam polarimetry using the Møller Polarimeter at beam energies up to 11 GeV at presently achieved levels of accuracy (3%),
- Measure the absolute energy of the electron beam at energies up to 11 GeV at about $5x10^{-4}$ accuracy.

3. Technical Approach to meet the Upgrade Hall A System requirements

The envisioned program for Hall A is based on the assumption that the beamline components will be upgraded to accept 11 GeV beam. This program includes:

- Continued use of the pair of High-Resolution Spectrometers (HRSs).
- Extending kinematic reach with general-purpose third-arm systems. Existing examples of these systems are the Hall A septum magnets, the Deep-Virtual Compton Scattering detector system, the 'BigBite' spectrometer, and a large neutron detector.
- Future major installations that take advantage of the large available floor space.

The above program requires upgrading the beam line instrumentation capable of measuring beam energy and polarization up to 11 GeV. The beam transport modifications required to deliver up to 11 GeV to Hall A are part of the Accelerator System - Beam Transport scope.

3.1 Møller Polarimeter

The present Hall A Møller polarimeter has an operational range of 0.8 – 6 GeV. The lower limit is set by the spectrometer acceptance - position of the various magnets, their apertures and collimators, as well as the field strengths. The upper energy limit is set by beam deflection due to field leakage in the magnetic shield insertion of the Møller dipole. To extend operation of the Møller polarimeter to beam energies of up to 11 GeV, the following modifications are required:

- Move ‘Q1,’ the first quadrupole after the Møller target, downstream by 40 cm.
- Install an existing, refurbished quadrupole similar to Q1 with its magnetic length center located 70 cm from the Møller target.
- Install a beam line corrector. Increase magnetic shielding of the beam aperture inside the Moller dipole to reduce beam deflection at higher beam energies.
- Operate the Møller dipole at a reduced bending angle - from the present 10 degrees to 7.3 degrees. Move the Møller electron detector package by 10 cm closer to the beamline to compensate for the reduced bending angle.

3.2 Compton Polarimeter

The Hall A Compton polarimeter determines the absolute polarization of the electron beam by utilizing Compton backscattering of polarized light from polarized electrons. In brief, the Compton polarimeter consists of a magnetic chicane made of four dipole magnets over about 15 m. The chicane displaces the beam vertically down by 300 mm where it interacts with polarized light confined in a High-Finesse Fabry-Perot cavity, injected from a 1064 nm infrared laser. The backscattered photons and the recoil electrons are detected in a $PbWO_4$ electromagnetic calorimeter and silicon microstrip detector, respectively.

The Compton polarimeter chicane has been designed to operate up to a maximum beam energy of 8 GeV. This limit is due to maximum pole-tip field of 1.5 T for the 1 m long dipoles in the chicane. The goal is to increase the dynamic range of the polarimeter without sacrificing low energy performance while retaining as much of the existing instrumentation as possible.

The present beamline dipoles will remain intact, reducing the beam displacement in the chicane. This requires raising the lower two dipoles along with the optics setup and the photon calorimeter by 82 mm. To accommodate these changes, the beamline vacuum system of the Compton polarimeter also needs to be modified. With reduced bend angle in the chicane, electron detection becomes more difficult at lower energies. However, with the presently planned green laser upgrade for the 6 GeV program, electron detection can be extended down to 1 GeV even with reduced bend angle.

The present electron detector is fixed with respect to the primary beam and can detect Compton scattered electrons at distances of 5 to 34 mm from the beam. The size of the detector is optimized to cover the Compton spectrum up to 6 GeV. For higher energy operation, it will be necessary to upgrade the electron detector. The size of the detector will be increased and it will be mounted on a precision motion system, which must then be integrated with the present Compton polarimeter control system.

3.3 ARC Energy Measurement

Presently, the energy of the electron beam reaching the Hall A target is measured with an accuracy of 100 ppm by measuring the change in the electron beam trajectory when subjected to a well-known magnetic field. The system hardware is composed of nine identical dipoles powered in series and two beam-trajectory measuring devices. Eight of the dipoles are part of the hall's beam transport arc. The ninth dipole, located outside the arc enclosure, is equipped with a traveling-coil field-integrating measurement system with 10 ppm precision. The magnetic field of the nine dipoles was measured under controlled conditions allowing cross-referencing of the magnets. Each beam-trajectory device is composed of two wire scanners, which allow determination of the position and angle of the electron beam at the entrance and exit of the hall's beam transport arc.

For the 11 GeV upgrade of the arcs the present C-style arc dipoles with an improved power supply can easily deliver enough field (~0.9 15 Tesla) of adequate quality to deliver 11 GeV beam to Hall A. Extending the ARC Energy measurement system to 11 GeV is a matter of extending the present calibration of the eight arc dipoles relative to the ninth dipole to the higher field region. The calibration plan, fully documented in JLAB-TN-08-005, involves the systematic shuffling of the 8 dipoles from the tunnel onto the existing, fully operational traveling-coil field-integrating measurement system for measurement at the higher fields, while maintaining the hysteresis history for the entire string.